American Petroleum Institute

Rotating Equipment Balancing Specifications

Formulas, Tolerances & Standards Reference

1. Overview

API balancing standards govern the allowable residual unbalance in rotating machinery used in petroleum refining, petrochemical, and natural gas processing. The primary standard is API 610, which defines the 4W/N balance tolerance formula. This is approximately equivalent to ISO Grade G0.7 — roughly 1.5× more stringent than ISO G1.

2. Primary Balance Tolerance — API 610

The maximum allowable residual unbalance per correction plane is defined by the following formula:

API 610	Maximum Allowable Residual Unbalance per Correction Plane

$$U\_res \ = \ 4W \ / \ N$$

U_res = Residual unbalance per correction plane (oz·in or g·mm)

W = Rotor weight (lb or kg)

N = Maximum continuous operating speed (RPM)

> **NOTE** This tolerance is referenced to the bearing journals (not the two balancing planes). It corresponds approximately to ISO 1940 Grade G0.7.

3. ISO 1940 Balance Quality Grade Relationship

The ISO 1940 standard defines balance quality grades that relate permissible specific unbalance to operating speed. The relationship is:

ISO 1940	Permissible Specific Unbalance

$$e\_per \ = \ U\_res \ / \ m \ = \ (G \times 9549) \ / \ N$$

e_per = Permissible specific unbalance (g·mm/kg or oz·in/lb)

`m` = Rotor mass (kg or lb)
`G` = Balance quality grade (e.g. G0.7, G1, G2.5, G6.3)
`N` = Operating speed (RPM)
`9549` = Unit conversion constant = 60 × 1000 / 2π

4. Permissible Residual Unbalance per Plane

For a two-plane balance check referenced to the bearing journals, the permissible unbalance per plane is:

Two-Plane Balance | Permissible Unbalance per Plane

$$\text{U\_per} \; = \; (\text{e\_per} \times \text{m}) \; / \; 2$$

`U_per` = Permissible unbalance per plane (g·mm)
`m` = Total rotor mass (kg)
`÷ 2` = Distributes across the two correction planes

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5. Balance Grade Comparison

The table below shows how API tolerances compare to ISO grades at a reference speed of 3,000 RPM:

Grade	Typical Application	e_per at 3,000 RPM	Precision
G 0.7	API 610 assembled rotor	2.2 g·mm/kg	Most stringent
G 1.0	API 610 components (older spec)	3.18 g·mm/kg	High
G 2.5	API 610 impellers (current)	7.96 g·mm/kg	Standard
G 6.3	API 671 couplings (if specified)	20.0 g·mm/kg	General

6. Residual Unbalance Test Acceptance

After final balancing, a residual unbalance test is performed while the rotor remains on the balancing machine. Results are plotted on a polar plot. The acceptance criterion is:

Polar Plot Acceptance Criterion

$$\text{r\_polar} \; \leq \; \text{U\_res} \; = \; 4W \; / \; N$$

`r_polar` = Radius of circle traced on polar plot
`U_res` = Maximum allowable residual unbalance = 4W/N

> **NOTE** If r_polar > U_res, the rotor MUST be rebalanced and retested before acceptance.

7. Unit Conversion Formulas

Unit Conversion | oz·in to g·mm

$$1 \ oz{\cdot}in \ = \ 720 \ g{\cdot}mm$$

`oz·in` = Ounce-inch (imperial)
`g·mm` = Gram-millimetre (SI)

API 610 Tolerance | SI Form (g·mm)

$$U\_res \ = \ (4 \times W[kg] \times 1000) \ / \ N$$

`W[kg]` = Rotor weight in kilograms
`N` = Speed in RPM
`× 1000` = Converts to g·mm units

API 610 Tolerance | Imperial Form (oz·in)

$$U\_res \ = \ (4 \times W[lb]) \ / \ N$$

`W[lb]` = Rotor weight in pounds
`N` = Speed in RPM

8. Key API Standards Summary

Standard	Equipment Covered	Key Balance Requirement
API 610	Centrifugal pumps	4W/N tolerance; G2.5 for impellers
API 611	General purpose steam turbines	4W/N tolerance
API 616	Gas turbines — refinery service	4W/N tolerance
API 617	Centrifugal compressors	4W/N tolerance + residual unbalance test

| API 671 | Special purpose couplings | ISO G6.3 or AGMA Class 9 (>3,800 RPM) |
| API RP 684 | Rotordynamic tutorial / all equipment | Lateral critical speeds, unbalance response |

9. Coupling Balancing Requirements (API 671)

Couplings are governed by more specific requirements depending on operating speed:

Operating Speed	Requirement
All speeds	All-metal flexible element spacer couplings: ANSI/AGMA 9000 Class 9
> 3,800 RPM	Must meet ISO 10441 or API 671 for component & assembly balance
If specified	Couplings balanced to ISO 1940-1 Grade G6.3

10. Component Balancing (API 610 / IOGP JIP33)

Individual rotating components such as impellers must be dynamically balanced before assembly:

Component	Balance Requirement	Minimum
Impellers	ISO 21940-11 Grade G2.5	7 g·mm (0.01 oz·in) — whichever is greater
Inducers	ISO 21940-11 Grade G2.5	7 g·mm (0.01 oz·in) — whichever is greater
Hubs (pre-keyway)	ISO 1940-1 Grade G1.0	Per older API 610 8th ed. (since revised)
Spare rotors	Same as main rotor	Must match primary rotor balance spec

> **NOTE** High-speed balancing at operating speed requires the purchaser's specific approval, and acceptance criteria must be mutually agreed upon between purchaser and vendor.